

Spin-resolved electronic structure studies of ultrathin films of Fe on singular and vicinal GaAs

M. Spangenberg¹, E.A. Seddon¹, E.M.M. McCash², T. Shen³,
S.A. Morton⁴, D. Waddill⁵ and J. Tobin⁴

¹CLRC Daresbury Laboratory, Keckwick Lane, Daresbury, Cheshire, UK

²Department of Chemistry, University of York, Heslington, York, UK

³Joule Physics Laboratory, University of Salford, Salford, Greater Manchester, UK

⁴Lawrence Livermore National Laboratory, 7000 East Ave., Livermore, CA 94550

⁵Department of Physics, University of Missouri-Rolla, Rolla, MO 65409

Recently, there has been considerable interest in the study of spin injection at ferromagnetic semiconductor heterojunctions and ferromagnetic metal – semiconductor contacts^{1,2,3,4}. Studies of n-type semiconductors have demonstrated spin-coherent transport over large distances⁵ and the persistence of spin coherence over a sizeable time scale⁶. Clearly such investigations have been stimulated by the potential of the development of ‘spintronics’, electronic devices utilising the information of the electron spin states. To understand and improve the magnetic properties of ultrathin Fe films on GaAs has been the aim of many research groups over recent years. The interest in this system has both technological and fundamental scientific motivations. Technologically, Fe on GaAs may serve to realize spin electronic devices. From a fundamental science point of view, Fe on GaAs serves as a prototype for studies of the interplay between the crystalline structure and morphology of an ultrathin film, its electronic structure and the long range magnetic order it exhibits.

In contrast to the attention given to Fe on variously prepared GaAs substrates, the magnetism of Fe on vicinal GaAs substrates has received scant attention. This in spite of the fact that films grown on vicinal substrates present a number of advantages and opportunities. For example, they are known to exhibit enhanced structural homogeneity, surface diffusion tends to follow well mapped patterns (the quasi-periodicity has been exploited to produce quantum wires) and there is an additional degree of control of the film growth beyond those associated with temperature and substrate surface composition⁷.

In a preliminary combined spin-polarized secondary electron spectroscopy, photoelectron spectroscopy and LEED study (carried out on the SRS, Daresbury Laboratory) of the remanent magnetic properties of Fe on singular and vicinal (3° offset) GaAs we have shown both that the various magnetic phases formed are dependant upon the Ga to As surface composition of the substrate and that they evolve in characteristic (but not well understood) ways with Fe overlayer thickness⁸. A remarkable feature in this system, which illustrates the importance of the Fe overlayer/substrate interaction, is the magnetic anisotropy; the easy axis of the Fe films on Ga-terminated substrates is perpendicular to that for As-terminated substrates^{9,10}.

These measurements were followed up with combined spin-resolved photoemission and magnetic linear dichroism experiments on Fe deposited on vicinal (offset by 3° and 6°) or singular GaAs substrates on Beamline 7 at the ALS in collaboration with Elaine Seddon of CCLRC Daresbury Laboratory, Dan Waddill of The University of Missouri-Rolla and James Tobin Of Lawrence Livermore National Laboratory. The GaAs(100) substrates were available for film deposition at room temperature after substrate decapping *in-situ* (by thermal annealing),

at the ALS. By mounting both singular and vicinal GaAs substrates on the same sample tile the same growth conditions applied for both films facilitating direct comparison. The surface quality was monitored using LEED. The following data were obtained, high resolution spin-integrated valence bands, the spin-resolved valence bands and their energy dispersion, the film thickness dependence of the spin-resolved valence bands, magnetic linear dichroism data on the Fe3p and Fe2p core levels at a variety of photon energies.

The experiments, which were performed with Dr. Simon Morton and Dr. Jim Tobin in November of 2000 have produced considerable amount of interesting results. The significant differences in the spin-resolved valence bands between *ca.*20 Å thick Fe films on singular and vicinal (3°) GaAs are illustrated in Fig.1. As the terrace width is *ca.*55 Å the spectral differences are not due to step-localized features.

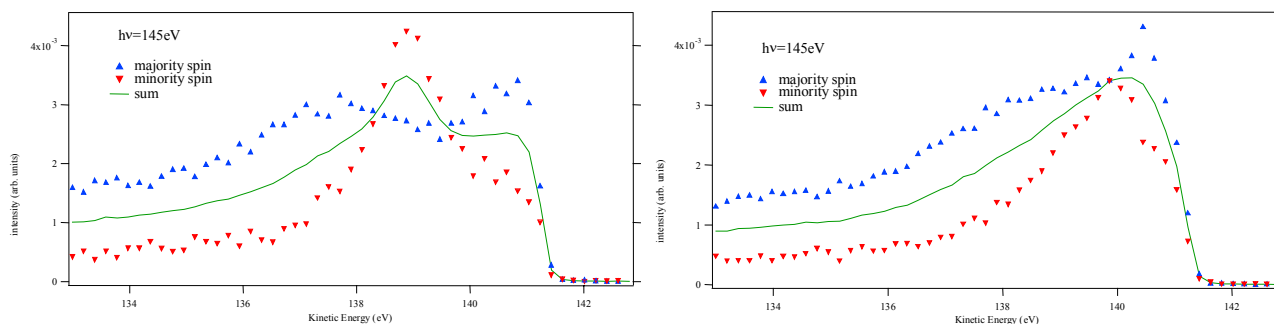


Figure 1
Spin-resolved valence band photoemission results for Fe on singular GaAs (left) and Fe on vicinal (3°) GaAs (right).

Other interesting results include the following. At low film thicknesses, Fe deposited on singular substrates was found to have a lower Curie temperature than Fe on vicinal substrates. Fe deposited on singular substrates reveals a larger energy dispersion of the spin-resolved valence bands than Fe on vicinal substrates. Only marginal differences can be seen between the spin-resolved valence bands of Fe deposited on 3° stepped GaAs substrates and Fe deposited on 6° stepped GaAs substrates. Also, in contrast to the valence band studies, the linear magnetic dichroism results obtained for these samples are very similar.

Further experiments at ALS during oct 2001 enabled us to obtain considerably more interesting results. Whilst the detailed analysis of the results is still underway, Fig.2 shows a large contrast of the valence band spectra of Fe versus incident photon energy between that on a singular and a vicinal substrate. The strong feature on the left in Fig.2 was found to be sensitive to the thickness of the Fe layer and the origin of which is still not yet clear at the present stage.

In summary, the experiments at the ALS have been extremely rewarding. They have answered some questions, clarified our thinking on others and raised yet other questions for which we have no answers at the moment. The run has, however, shown that further access to the ALS is needed to fully understand this fundamental and technologically important system.

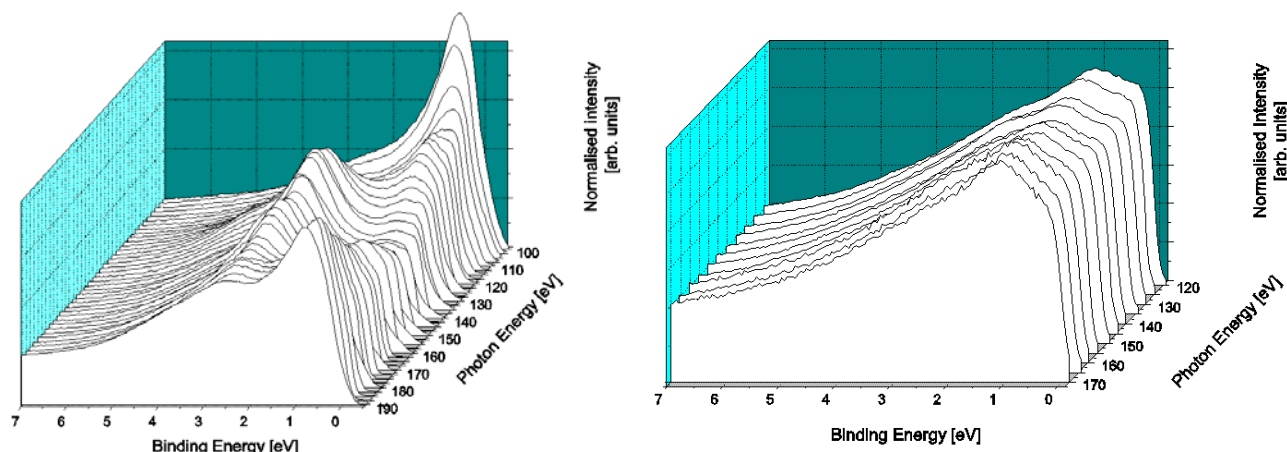


Figure 2.

Valence band spectra of Fe, normalised to the secondary electron tails, versus photon energy for films on singular substrate (left) and on 6 degree vicinal substrate (right).

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Principal investigator: E. A. Seddon, CCLRC Daresbury Laboratory, Daresbury, Warrington Cheshire, WA4 4AD, UK, Email: e.a.seddon@dl.ac.uk, Telephone: +44 1925 603245, fax +44 1925 693124